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Vol. 9(19), pp. 1516-1521, 8 May, 2014
DOI: 10.5897/AJAR2013. 7293
Article Number: 1EF100944546
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Sources and rates of nitrogen in summer corn under no-tillage on winter cover crops

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Received 28 April, 2013; Accepted 1 August, 2013

Cover crops occupy and protect the soil during winter and also provide nutrients to tropical soils. The aim of this study was to evaluate the effect of sources and levels of nitrogen applied to a summer corn crop cover in succession to cover cropsunder no-tillage. The experimental design consisted of randomized blocks with four replications in a scheme with subdivided plots. The main plot was composed of two crops that preceded corn; common oat (*Avena strigosa Schreb.*) and forage turnip (*Raphanus sativus*), and a winter fallow area (weed). The subplot consisted of two nitrogen sources (urea and ammonium sulphate), and the splits of each subplot were constituted by four rates of nitrogen (0, 30, 60 and 120 kg ha^{-1}). The following production components were analyzed: ear diameter, kernel rows per ear, mass of 1000 grains and grain yield. Corn grown after oat presented responses to nitrogen fertilization for mass of 100 grains and hence to grain yield.

Key words: *Zea mays*, nitrogen fertilization, urea, ammonium sulphate

INTRODUCTION

Corn is a crop of major economic importance for the state of Paraná, representing 26% of the Brazilian production, with about 12.61 million tonnes (Demarchi, 2010). First crop corn in the state has been increasing in yield potential due to the technology used by producers. Nitrogen is one of the most important nutrients for plant growth (Fageria and Moreira, 2011), especially corn. The recommendation of nitrogen fertilization on summer corn coincides with different species that occupy the soil during winter, what may affect the stocks of nitrogen (N) in the soil and nutrient utilization by the plant. According to Fernandes and Libardi (2012), the advancement and consolidation of the direct drilling system in tropical soils with soil re-covering increment N in the soil, what leads to new agricultural recommendations for crops.

Another aspect to be considered in what concerns to the nitrogen fertilization of corn is the source of mineral nitrogen. Ammonium sulphate and urea are the two most

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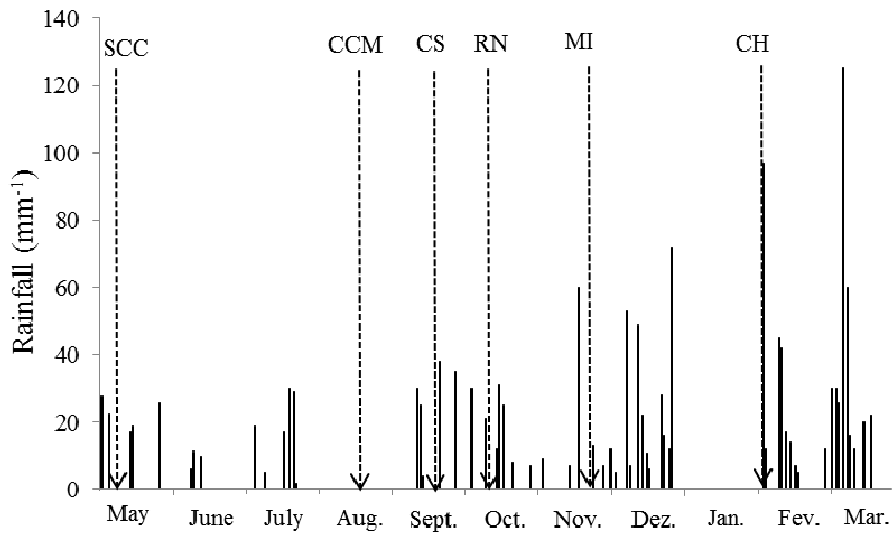

Figure 1. Rainfall recorded during the experiment. Seeding cover crops (SCC), cover crop management (CCM), corn seeding (CS), male inflorescence (MI), rates of nitrogen (RN), corn harvest (CH).

used N sources in Brazilian agriculture, possibly for being less expensive and more readily available on the market (Barbosa Filho et al., 2005). Losses by volatilization when using ammonium sulphate are not large, however, such source typically has a cost per unit of N far superior to urea (Lara Cabezas et al., 2008). Soil cover crops have capability to provide nutrients for subsequent crops and increase organic N in the soil (Sainju et al. 2005). Such practice is gaining more and more space in the agricultural areas of southern Brazil, where there has been a search to optimize the direct drilling system with crop rotation (Doneda et al., 2012).

Legume species are an important source of nitrogen to the soil through biological fixation (Silva et al., 2006), and are also a great alternative for soil decompression, resulting in benefits for plants in succession (Rosa et al., 2012). Grasses increase the permanence of straw on the soil surface by the higher C/N ratio, and thus, cause lower decomposition rates with greater persistence (Torres et al., 2008). Silva et al. (2006) observed maximum technical efficiency of nitrogen on corn with rates of 205 and 175 kg ha^{-1} in succession to black oats and forage turnip, respectively. Lourente et al. (2007) found maximum corn yield under no-tillage, when sown in succession to wheat and common oat at rates of 140 and 137 kg ha^{-1}of nitrogen. According to Roselem et al. (2004), graminoids have elevated ratio C/N and dry matter production, however, when corn is being cultivated in succession in tropical areas, it is necessary to perform nitrogen supplementation. The aim of this study was to evaluate the effect of preceding winter crops, sources and rates of nitrogen applied to the summer corn crop cover on crop yield components, consolidated under no-tillage.

MATERIALS AND METHODS

The work was conducted under field conditions in the agricultural year 2012 to 2013, in an agricultural area in the municipality of Medianeira-Pr, which presents as its geographic coordinates longitude 54° 04'16'' W, latitude 25° 20'09''S and altitude of 286 m. The climate is humid subtropical with hot summers, with an annual average of 21°C (Iapar, 2013). The average monthly rainfall are shown in (Figure 1).

The soil used in the experiment was collected on the same property, at a depth of 0 to 20 cm and classified as eutroferricOxisol (LVe) (EMBRAPA, 2006). Prior to the experiment, soil sampling was conducted to determine its chemical characteristics at a depth of 0 to 20 cm, the results were: 16.53 g dm^{-3} organic carbon; pH ($CaCl_2$) 5.30; 19.90 mg dm^{-3} of P, 0.51 cmol$_c$ dm^{-3} of K^+; 6.56 cmol$_c$ dm^{-3} of Ca^{2+}; 2.75 cmol$_c$ dm^{-3} of Mg^{2+}; 4.61 cmol$_c$ dm^{-3} of H^+ Al; CTC 14.43 cmol$_c$ dm^{-3} and 68.05% of base saturation.

The experimental design consisted of randomized blocks with treatments arranged in a scheme with subdivided plots, with four replications. The plots, measuring 100.8 × 4.20 m, were established by winter cover crops: common oat (*Avena strigosa* Schieb.), forage turnip (*Raphanus sativus*) and a control treatment (witness), without growing cover crops (fallow). Subplots measuring 33.6 × 4.20 m, with two sources of nitrogen(urea 46%, ammonium sulphate 21%), and subsubplots 16.8 × 4.20 m four rates under cover fertilization in the corn crop (0, 30, 60 and 120 kg ha^{-1}). The cover species were mechanically sown in winter, 5th May 2012, in succession to a soybean crop, with its sowing density following the technical recommendation for each crop. Plant desiccation was performed on 16thAugust 2012 by using herbicide glyphosate (2.275 g i.a. ha^{-1}) and subsequent mechanical handling through a crusher model Triton©.

Corn was sown mechanically, on 16th September 2012, with basic fertilization in all plots of 210 kg ha^{-1} of NPK formulation 13-06-9. The corn used was the hybrid Pioneer 30F53, considered as medium cycle, recommended for normal season planting (summer). Density of 4.1 seeds per meter was used, with distance of 0.70 m between lines, totalizing 58,000 plants ha^{-1}. The seeds were treated with Thiamethoxam in a rate of 210 i.ag/100 kg seeds. For the control of weed in post-emergence, 1650 g of atrazine i.a. ha^{-1} +

Table 1. Diameter of ear, rows per ear, 1000-grain weight and grain productivity of maizeabout cover crops and rates of nitrogen.

Cover crops	Diameter of ear	Rows per ear	1000-grain weight	Yield (kg ha^{-1})
Black oat	51.15	16.42	315.06	9543.53
Oilseedradish	54.70	16.70	316.57	10140.99
Fallow	52.18	16.50	315.05	10259.13
CV (%)	19.59	2.43	3.42	11.12
Source (S)				
Urea	53.59	16.53	318.46	9949.12
Amm.Sulphate	51.76	16.55	312.66	9884.75
CV (%)	18.27	2.58	6.12	6.72
Teste F		**Values of F**		
Cover crops (C)	1.004n.s.	4.092n.s.	0.209n.s.	3.822n.s.
Source (S)	0.865n.s.	0.036n.s.	2.166n.s.	0.220n.s.
Rate (R)				
CV (%)	18.58	4.07	4.84	9.97
Linear reg.	0.003n.s.	2.090n.s.	36.077 **	8.381 **
Quadratic reg.	1.331n.s.	7.319 **	0.716n.s.	3.818n.s.
Interaction (CxS)	1.100n.s.	5.094 *	0.133n.s.	3.270n.s.
Interaction (CxR)	0.907n.s.	0.654n.s.	0.926n.s.	1.591n.s.
Interaction (SxR)	0.951n.s.	1.591n.s.	2.079n.s.	0.180n.s.
Interaction (CxSxR)	0.889n.s.	2.273 *	1.311n.s.	0.587n.s.

Means with different small letters in the columns are statistically different at (**) 1% and (*) 5% of probability or no significant (n.s.) Tukey test.

148 g of mesotrionei.a. ha^{-1}, were applied, when corn plants presented six fully expanded leaves. The application of nitrogen rates to the cover in the subplots was performed manually beside the plants when they were in V6 (six fully expanded leaves).

During corn harvest, the two central rows of each plot were sampled, discarding 0.50 m from each end. Five ears of each line were collected and separated to determine the following yield components: number of grain rows per ear (by counting the grain rows of each ear, individually); ear diameter (with the aid of a caliper); mass of 100 grains (average mass of five subsamples of 100 grains corrected to 13% moisture) and productivity (mass of grains produced in the two central lines of each plot corrected to 13% moisture by estimating the productivity kg ha^{-1}). The results were subjected to analysis of variance, by using the F test at 5% for comparing cover crops and sources of nitrogen, and polynomial regression analysis, for studies of N rates on coverage, using the statistical package Assistat® version 7.5 beta (Silva and Azevedo, 2002).

RESULTS AND DISCUSSION

There was adequate rainfall distribution in the early stage of crop development with good rainfall until close to the male flowering, even after the application of N in the cover (Table 1). Ear diameter suffered no influence (p <0.05) of the studied factors and the interaction between them (Table 1), what disagrees with Ohland et al. (2005) who observed an increase in ear diameter in the succession hairy vetch/corn regardless of the rate of N applied. Lourente et al. (2007) found a significant effect only in function of N rates for ear diameter.

The number of kernel rows in the ear was not significant for the preceding crop and nitrogen source, but significant for the interaction (Figure 2), as well as for rates of N applied to the cover when corn was sown on fallow. Souza et al. (2011) found results that support this work, in which N sources had no effect on variable kernel rows per ear in two years of cultivation in Selvíria (MS). Meira et al. (2009) and Casagrande and Fornasieri Filho (2002) also found no differences between sources in the component number of kernel rows per ear.

There were significant effects (p<0.05) in the interaction between cover crops and nitrogen sources on the number of kernel rows in the ear (1). Because of the interaction, the deploymentwill be analyzed in Table 2. One can notice in the interaction that the succession forage turnip/corn resulted in 19.90 kernel rows with ammonium sulphate being used as nitrogen source. The number of kernel rows in the ear was significantly influenced by N rates when corn was sown in the fallow area. The quadratic model was the one that best fit to the data, with maximum response obtained by the derivative of the equation, with 17.20 kernel rows per ear, at a rate of 67 kg ha^{-1} of ammonium sulphate (Figure 2D). When

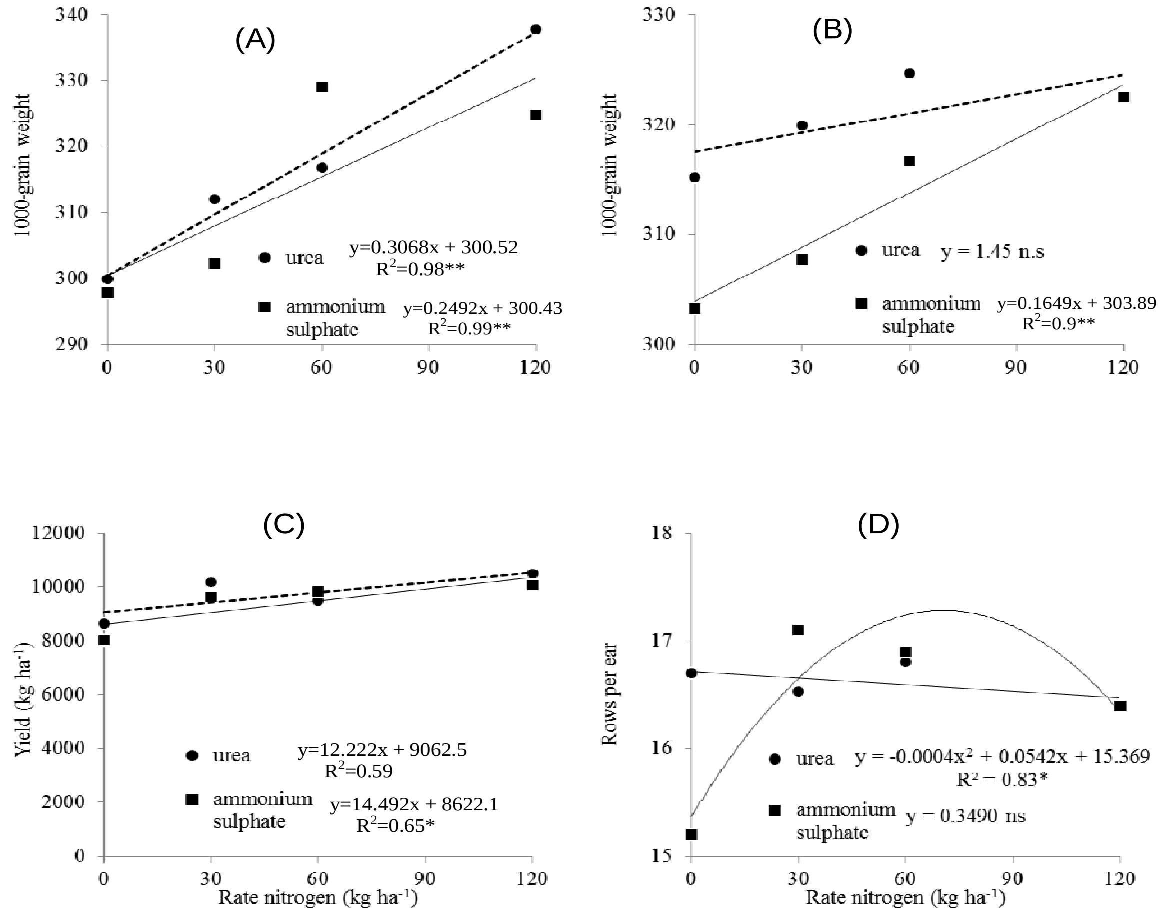

Figure 2. 1000-grain weight, Black oat (A); Oilseed radish (B); Grain productivity, Black oat (C); Diameter of, Fallow (D); the relative rates of nitrogen.** = significant at 1% probability; n.s. = not significant.

Table 2. Unfolding of the interaction cover crops/sources.

Cover crops	Source	
	Urea	Amm.sulphate
Black oat	16.50^{aA}	16.35^{bA}
Oilseed radish	16.50^{aB}	16.90^{aA}
Fallow	16.60^{aA}	16.40^{bA}

Means followed by the same letter (lowercase in the columns for comparison between cover crops. Capital letters in the lines comparing sources show no difference (Tukey, 5%).

the preceding crop was common oat and forage turnip, there was no response to nitrogen fertilization. Casagrande and Fornasieri Filho (2002) found no effect of N rates (0, 30, 60 and 90 kg N ha^{-1}), in the form of urea in the number of kernel rows per ear.

The mass of 1000 grains was significantly influenced by nitrogen fertilization applied to the coverage in an increasing way with linear adjust when corn was cultivated in the succession common oat/corn with maximum values of 338 g with a rate of 120 kg ha^{-1} of urea (Figure 2A), supporting what was stated by Lourente et al. (2007) who studied the effect of sources and rates of N in the soil and observed a linear increase of mass of 1000 grains up to the maximum rate of 200 kg ha^{-1}. Oliveira and Caires (2003) also found a linear increase of the mass of 100 grains in succession to common oat, and pointed out that such yield component was crucial to increase grain yield, using rates of 0, 30, 60, 90 and 120 kg ha^{-1}of N. In the succession forage turnip/corn only ammonium sulphate provided response on the mass of 1000 grains (Figure 2B), and in the succession fallow/corn there was no influence of nitrogen fertilization.

Soratto et al. (2011) found no effect of sources and levels of nitrogen applied to the coverage of winter corn crops cultivated in succession to millet. Lourente et al. (2007) observed maximum mass of 1000 grains for corn in succession to wheat, with values of 291 g by applying 168 kg N ha^{-1}. Ohland et al. (2005) found that corn seeding after hairy vetch showed higher mass of 1000 grains compared to corn sown after forage turnip, regardless of nitrogen levels,with average values of 353 g.

For grain yield, the results were significant ($p<0.05$) for nitrogen rates, and not significant for the previous crop and N source, as well as for interaction. Although there were no significant differences for interaction, regardless of the previous crop and N sources, corn fertilized with urea produced 10,490 kg ha^{-1}, and with ammonium sulphate, 10,054 kg ha^{-1}, showing no evidence of the maximum technical efficiency rate (Figure 2C). Possibly the lack of response of the sources happens due to the fact that soon after the application of N there were rains, reducing losses by volatilization, especially urea.

Corn grain yield was not influenced by N rates in coverage when sown in succession to forage turnip and fallow area. Lourente et al. (2007) found higher corn yields when the grain was sown in succession to fallow and forage turnip in the absence of nitrogen fertilization. Silva et al. (2006) observed maximum productivity for the succession common oat/corn with 8,280 kg ha^{-1}, with the application of 205 kg ha^{-1} of N. When corn was sown after forage turnip, the maximum productivity level was 8,020 kg ha^{-1}obtained at a rate of 175 kg ha^{-1}of N.

Soratto et al. (2010) when working with four N sources (urea, ammonium sulphate, starea and entec) in succession to soybean in the region of Chapadão do Céu (GO), found that ammonium sulphate provided the highest corn grain yield in relation to starea, however, it did not differ from other sources. Kappes et al. (2009) observed a significant increase in grain yield with the application of 70 kg ha^{-1}of N, regardless of the source used (sulphate and ammonium, urea and entec). Roselem et al. (2004) observed higher corn productivity in succession to millet with nitrogen fertilization applied to the coverage; however, such fertilization of 120 kg ha^{-1}was not enough to supplement the needs of the crop after common oat. Silva et al. (2012), in a study in western Paraná, verified yields of 3.928 kg ha^{-1} of summer corn with rates of 7 tonnes per ha^{-1} of poultry litter being used as nitrogen source.

Conclusion

Corn grown after common oat showed responses to nitrogen fertilization for mass of 1000 grains and hence for grain yield.

Conflict of Interests

The authors have not declared any conflict of interests.

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